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1. **Regional Economics and Environmental Economics**

A search for linkages - theoretical, methodological or empirical - between regional economics and environmental economics may start from two different though complementary departures. One may try to identify environmental aspects in spatial economic theories, models or applications. Alternatively, one may seek for clear spatial dimensions in existing environmental economic analyses. In the present publication we will mainly adopt a blend of these two research explorations. The first section of our contribution sets out to present some main features of both regional and environmental economics with a view on the identification of linkages between these two subdisciplines in economics. We will first start with regional economics, followed by environmental economics.

Although the origin of **regional economics** dates back to the 19th century (mainly Von Thünen) and the first part of the 20th century (Weber, Hotelling, Christaller, Lösch), the real genesis started in the 1950s (see for a historical survey Paelinck and Nijkamp 1975 and Ponsard 1983). One of the pioneers in regional economics, Walter Isard, recognized that distance friction and transportation costs on the one hand and agglomeration economies on the other hand were largely responsible for the heterogeneity in location patterns of both firms and households (see Isard 1956). The awareness of spatial frictions and opportunities in the behaviour of economic actors induced also a profound interest in urban economics, housing market economics, regional labour market economics, and transportation economics. Next to regional economics in a strict sense, we may also distinguish **regional science** as a broader interdisciplinary approach to spatial phenomena, including also geography, planning, architecture, political science and so forth. It is evident that in this broader framework environmental issues find also a 'natural niche'.

Environmental economics has a slightly different development pace. Despite the early recognition of the existence and the implications of external effects in a market economy (Marshall, Pigou, Hotelling), it was mainly the wide-spread concern on the observed decay in our quality of life and in ecosystems conditions which prompted as of the 1960s a broad interest in the economics of the environment (see e.g., Boulding 1969, Mishan 1967, Kneese 1965, Krutilla 1972). The Club of Rome studies generated especially in the 1970s a further interest in environmental economics, but - with a few exceptions - it lasted until the 1980s before an extensive package of environmental economics journals and (hand)books entered the academic market. This is not the right place to dwell extensively on the history of environmental economics, but for more details we refer to Crocker (this Handbook).

In an early stage already of the development of both regional and environmental economics several intricate links can be observed, In regional economics, for example, we saw the application of (multi-regional) input-output models to environmental and pollution issues (see e.g. Cumberland 1966, Isard 1969, 1972, Leontief 1970 and Muller 1979), while also the presence of environmental externalities was analyzed in a spatial-economic welfare context (see e.g. Nijkamp 1977). In environmental economics, on the other hand, the intricate relationship between environment assets and spatial economic behaviour was also clearly realized, as is witnessed by the great many valuation studies on natural parks, where travel cost methods became a popular analytical tool (see e.g. Burton 1971), and studies on urban pollution valuation, where revealed preference methods showed a great scientific potential (see e.g. Bartik and Smith 1985).

One may thus conclude that there are many analytical connections between regional and environmental economic phenomena. These relationships may be unidirectional in nature, but may also show complicated feedback structures of modularly or hierarchically operating environmental-economic systems in space and time. The nature of such interactions is depending on ecosystems' and human behaviour as well as on spatial-environmental policy. Clearly, environmental policy has a direct bearing on regional and urban development, while regional and urban policies have immediate implications for environmental quality (see e.g. Schnaiberg et al. 1986). This holds for command-and-control policies (e.g. prohibitions), but also for market-oriented policies (e.g. user pay strategies).

The twin character of space and environment is a direct result of the fact that environmental externalities - unpaid burdens imposed by polluters on other actors (see Verhoef in this volume) - are usually transmitted through the medium of space. In other words, environmental externalities are likely to show up as unpaid spatial spillovers (at various geographical scales, ranging from local to global). On the other hand, all space-related activities (e.g., residential locations, industrial development, transportation, etc.) are closely connected with environmental changes. For example, it has in this context become rather common to make a distinction between fixed (point) sources of pollution and mobile sources such as vehicles. The previous considerations can be further substantiated by the following observations on the twin nature of space and environment:

- Space is the **geographical medium** (or 'physical market') for environmental externalities in a broad sense; this applies to global environmental change, but also to local issues like noise annoyance, soil pollution, etc.
- Space is of a **heterogeneous nature,** with the consequence that environmental externalities have geographically discriminating, distributive impacts (e.g. recreational visits to attractive areas may pose an excessive burden on such areas).
- Space is a **scarce good** whose consumption (e.g. land use) has environmental implications and welfare effects for other members of society, now or in the future, here or elsewhere (e.g. environmental degradation processes in a global space-time context).

In conclusion, the relationship space-environment manifests itself as a complex nexus at the interface of regional economics and environmental economics. In the next sections we will pay more attention to the linkages between these subdisciplines in economics by addressing their mutual connections from a theoretical, modelling and policy perspective.

2. Integration of Spatial-Economic and Environmental-Economic Theory

Regional economics has built up a significant body of explanatory theoretical and operational frameworks for the analysis of the geographical dispersion and coherence of economic activities. Location theory (partial or general) may be regarded as the heart of regional economics. Its main aim is to identify the optimal spatial position of economic actors, based on cost or welfare criteria (see for an extensive survey of the literature Thisse et al. 1996).

The recognition of environmental externalities in **industrial location theory** may take place along several lines:

- The adoption of a 'polluter pays' principle. This implies that the costs of environmental damage caused by a producer have to be charged to the polluting firm. In a locational context this means that the social costs of environmental decay have to be incorporated in the locational costs of the private firm, so that the ultimate location decision would respect environmental quality conditions (see Markusen in this book).
- The adoption of a regulatory regime, based e.g. on zoning conditions. Although such environmental regulations are second-best solutions, they have in practice become rather popular, as their implementation is easier to exercise. Consequently, industrial environmental policy is often based on land use restrictions, at best supplemented by taxation schemes for environmental spillovers. Only more recently a combination of the two approaches, based on tradeable emission permits within a set of prespecified environmental quality conditions in a given area, have gained more popularity (see Klaassen **1995** and Verhoef et al. 1997; see also Koutstaal, and Tietenberg in this book).

The theory of **residential location decisions** runs more or less parallel to the above description of industrial location analysis. Environmental externalities may either be included in the prices or rents of dwellings (so that locational choices will internalize environmental externalities) or be taken into consideration on the basis of physical planning and zoning principles (see e.g. Guldmann and Shefer 1980). A particular case of spatial externalities may show up in the form of (positive or negative) neighbourhood effects. Such effects may also have an impact on the price levels (or rents) of dwellings and may be measured by using e.g. valuation studies based on hedonic prices or contingent valuation methods (see Part 3 of the present book).

It should also be recognized that a spatial system is usually **not a closed system,** but is facing various spatial economic and environmental interactions. Economic interactions may relate to trade flows, migration, transport etc., while environmental interactions may concern diffusion of pollutants or water flows, but also migratory birds or animals. This means that an open regional system is permanently in a state of flux, so that integrating the spatial interactions between different variables in different regions is fraught with many problems (see Braat and Van Lierop 1987). In the past many models in the area of integrated economic-environmental analysis were static in nature, but we observe nowadays a rapid emergence of spatial dynamic models, where the dynamics of a regional economy (e.g., based on investments, R&D, innovation, etc.) is linked to the dynamics of ecosystem (e.g., based on predator-prey evolution).

Seen from an open spatial systems' perspective, it is clear that a situation of global environmental sustainability is difficult to achieve (see also Giaoutzi and Nijkamp 1993, Pezzey 1989). Therefore, it seems more promising to address environmental sustainability issues at a meso (i.e., regional) level, as then it may be possible to attain a more practical and operational environmental policy and management strategy. Another reason why spatial dimensions are directly connected with sustainability issues is that the geographical subdivision has far reaching implications for the type of sustainaibility (e.g., weak, strong) that can be attained. Environmental externalities imply often a spatial transfer of environmental burdens to other areas, so that a situation of strong sustainability in an open system of (small) regions is likely not to be reached (see also Van den Bergh and Nijkamp 1997).

We will now turn to the way **environmental economics** has managed to include spatial(-economic) aspects in its analysis framework. Implicitly, the spatial dimensions of environmental externalities are abundantly present in many studies, ranging from transport externalities analyzed by Coase (1960) to general ecosystem's degradation analyzed by Van den Bergh (1996). Two major streams of analysis may be identified which pay explicit attention to geographical space.

First, a major part of the literature in the early days of environmental economics has been devoted to **valuation studies,** e.g. of tourist areas, natural parks, historical monuments etc. Past studies in this area can be found in Nourse (1967) and Wieand (1973). The main aim was to derive from actual behaviour or from the perceived importance regarding **these** assets their implicit socio-economic value in a situation where the presence of external effects prevented a straightforward market evaluation (cf. Randall and Castle 1985). Most of these studies were based on spatially discriminating externalities as a result of the geographical spread of pollutants or the geographical distribution of environmental assets. Common approaches were travel cost methods or willingness-to-pay methods for assessing a monetary value for the environmental asset concerned, an approach which has set the stage for the current popularity of contingent valuation studies and hedonic price studies, which have become a dominant stream in economic valuation analysis of environmental externalities (see Part 3 of this book). Such analyses may also offer a foundation for Pigouvian taxation schemes in a spatial setting. Such methods were often also included in social cost-benefit analyses of environmental policies, e.g. in relation to agricultural, infrastructural or urbanisation plans (see van Pelt 1993).

Another major spatial orientation in the environmental economics literature was concerned with the analysis of **interactions** between different regions, sectors or groups, e.g. trade, transport, emission of pollutants etc. Well-known examples of studies with a clear spatial connotation are noise annoyance studies, water pollution studies, and multi-regional input-output studies (including resources. and pollutants). Especially for policy assessment and predictive purposes the latter approach appeared to be very useful. Many interesting examples and spatial-economic theoretical contributions can be found in Schnaiberg ***et al. (1986).*** In the next section some further remarks on this approach will be offered.

This concise overview has clearly demonstrated that the space-environment linkage is multi-faceted and calls for research into various difficult analytical issues, such as the distributional impacts of policy (witness the NIMBY phenomenon), the analysis of environmental options in space, the management of common resources in a given area, or the establishment of spatial compensation schemes for environmental decay. Optimization models seeking to identify shadow prices for spatially discriminating environmental standards are good examples of innovative research in this area (see e.g. Hafkamp 1984). Other interesting concepts are the shadow project approach seeking for real-world compensation for the loss of environmental goods (see Klaassen and Botterweg 1976). Thus, there are many new perspectives for analyzing the linkages between the space-economy and the environment, in which land use and spatial behaviour are closely connected with environmental externalities.

3. Modelling the Spatial-Economic and Environmental-Economic Nexus

The element of space in environmental economics and the position of the environment in regional economics have been modelled in various ways in the past decades. Environmental-economic modelling has become a broad research area (see also Madsen et al. 1996). The analysis of the space-environment nexus provokes various questions on the interaction between land use and the environment, e.g. on the role of the environment as a productive resource or as a consumption item to be included in a welfare function, on the trade-off between un-priced and priced goods, on the interest of new generations (here or elsewhere) (see Van Pelt 1993). He claims that environmental policy has to be region-specific in light of distributional issues and site-specific attributes and human perceptions of environmental decay. But the modelling of such phenomena is fraught with a number of difficulties, partly of a methodological nature, partly of an empirical nature. There is not an unambiguous research tradition on spatial and environmental economic issues, but there are different research methodologies which will concisely be reviewed here.

First, there are several attempts to formally analyze - by means of partial statistical models or integrated equilibrium models - **spatial environmental externalities,** in the form of social costs incurred in the form of pollution (air, water, soil) emerging from the regional-industrial structure of a given area. Such studies started as a generalization of ‘space-less’ economic models, but focussed increasingly on broader environmental issues such as land use, nature conservation, quality of life or even urban monument conservation. Empirically they got also a much more concrete focus, e.g. on cities, islands, lakes, mountainous areas, or agricultural regions. In the eighties a wide variety of scientific efforts has been made to design operational planning and forecasting models for such issues (see for an overview Giaoutzi and Nijkamp 1993) (see also

Banister, this book). Later on, there was also growing interest in the environmentally disruptive impacts of tourism, recreation, intensified land use, development conflicts and extractive activities. It is increasingly recognized that effective policy measures are to be taken to reduce or eliminate the environmental externalities of such activities. Here the issue of sustainable development for ecologically vulnerable areas - with a focus on local and regional conditions - is at stake (see also Section 2). In this context, the notion of **regional** sustainable development is an important one (see Giaoutzi and Nijkamp 1993).

A second class of modelling contributions at the interface of regional and environmental economics - mainly of an applied nature - can be found in the field of **spatial interactions.** Such interactions may concern the distribution of pollutants over various regions or cities, such as transboundary air pollution, pollution of rivers crossing different areas, transport of solid waste as part of a materials chains, etc. Modelling such flows has already a long tradition, starting from the materials balance model which is essentially based on the law of conservation of materials and energy (see Ayres and Kneese 1969). Also the large number of transportation models with environmental decay components has to be mentioned here (see Verhoef 1996)(see also Rietveld and Button, this book). In a multiregional context, this issue provokes various distributional concerns which may have important policy implications. Examples are spatial compensation schemes for damage caused by environmental externalities from different regions, tradeable emission permits for pollution from different areas of a spatial system, and so forth. Such models are often used for spatial-environmental policy assessment. It is clear that the nature of policy solutions is in general dependent on the reciprocity of pollution effects and on the separability of the external (social) costs (in terms of marginal costs).

A complementary way of depicting economic-environmental interdependencies is the use of **multiregional input-output models** already alluded to above. In this approach the focus is on economic intersectoral linkages between different regions, represented in a closed form. Pollution, resource and energy implications of such interregional flows are then added through a balanced physically-oriented model, often based on an integration of materials balance notions and fixed input-output linkages. Important questions to be answered by using such models may be the regional implications of (possibly regional discriminatory) taxation schemes on environmental externalities, or the environmental implications of new industrial developments in one region on all other regions. Interesting empirical examples of such approaches can be found in Lakshmanan and Nijkamp (1983) and Hafkamp (1984). All such attempts offer a consistent and comprehensive picture of spatial environmental and economic interwovenness.

A more recent class of integrated spatial, economic and environmental models can be found in **spatial-economic (price) equilibrium** analysis and in **applied (or computable) general equilibrium** analysis (see Van den Bergh et al. 1996 and Ta kayama 1996). Such models describe spatially disaggregated, economy-wide equilibrium patterns, in terms of commodity (freight) flows or passenger flows. Spatial price equilibrium models are based on flexible prices clearing spatial excess demands and supplies for given transport costs structures (see also Takayama and Labys 1986). An extension of such models with spatial environmental externalities (e.g. environmental decay caused by pollution) is contained in Verhoef and Van den Bergh (1996, 1997). It is noteworthy that a similar approach can not only be found in the area of regional economics, but also at a wider scale of international trade theory (see e.g. Verbruggen 1996). Spatial dynamic environmental models with an evolutionary perspective are also increasingly coming to the fore, although most of these attempts are still rather theoretical (see Nijkamp and Reggiani 1997).

In the light of the previous concise overview, we may conclude that the modelling of environmental-economic phenomena in a spatial context has no doubt generated a wealth of inspiring scientific contributions which in many cases had also a clear policy relevance. Challenging tasks can, however, still be found in the following research fields:

- Design of **spatial-dynamic models** with nonlinear feedback loops so as to map out the complex environmental-economic linkages in a space-time setting including endogenous growth issues (see also Nijkamp and Reggiani 1997).
- Development of **common areal classification principles** for spatial-economic and environmental phenomena, using varying scale methods based on e.g. geographic information systems (GIS) (see e.g. Douven 1997).
- Development of a proper **spatial-environmental indicator system** which may be helpful in assessing plausible environmental parameter values in spatial-economic models.
- Establishing **critical threshold values** (safe minimum standards, carrying capacity etc.), which may be site-specific and which may also be helpful in risk (perception) studies often characterized by a strong geographical component (e.g., distance decay).
- **Integration** of analytical modelling results with **spatial-environmental policy issues** which may map out the complicated trade-offs of economic and environmental welfare components in a spatial context (including e.g. land use zoning or protected environmental areas):

4. Spatial-Environmental Policy Studies

Spatial environmental policies cover a wide range of government measures, such as (local and regional) taxation schemes or subsidies, land use zoning initiatives, regional environmental standards, industrial location strategies, infrastructure investments and the like. Such measures may be market-oriented or just be based on second-best principles; they may be of a control-and-command type or of a stimulating (or discouraging) nature; they may be strictly environmental in nature or address broader issues related to regional sustainable development. Spatial-environmental policy studies are normally based on analytical frameworks as described in the previous sections, but have also their distinct intrinsic merits and features. In general, such studies may be subdivided into two main categories, viz. **impact studies** and **decision support studies.** We will concisely describe both classes.

Impact studies are normally dealing with 'what-if' questions. The analytical tools have already been described in Section 3 (e.g., input-output models, spatial equilibrium models etc.). Such studies are particularly important, as in an open spatial-economic and environmental system interregional flows (e.g., goods, services, migration, pollution) may lead to spatially discriminating distributive effects which may form the roots of many conflicts. Clearly, both industrial policies and environmental policies may generate complicated spatial spillovers which may affect the welfare position of the regions at hand. For instance, public investment programmes, physical planning and infrastructural measures, land use zoning principles, establishment of regional environmental standards and the like will all affect the environmental quality of regions in an open spatial system (see for a broad review Schnaiberg et al. 1986). Interesting recent illustrations of such spatial-environmental policy studies can be found in a study of Gørtz (1996) on the regional consequences of environmental taxes, of Jensen and Stryg (1 996) on the spatially-distributive impacts of a taxation of fertilizers, and of Jensen-Butler and Madsen (1996) on the spatial-economic impacts of environmental measures in the transport sector. The results of such studies may also form an operational input for decision support studies in a multi-regional context.

Decision support studies aim to map out the trade-offs between different policy options, including distributional conflicts and environmental quality consequences. In a spatial context, these trade-offs are also reflected in different development opportunities of regions or places in a spatial system (see e.g. Nijkamp et al. 1992, and Forslund and Lindberg 1996). There is in general a multiplicity of actors, of regions, of regional environments and of policy objectives, which may be depicted by an operational spatial-environmental economic model as described above. In several cases however, research has to rely on ad hoc information, expert opinion etc., so that a precise assessment of the (socio-)economic and environmental implications of spatial-environmental policies is fraught with uncertainties.

In this context, the results of valuation and modelling studies are often fed into decision support analysis which may comprise various analysis frameworks. They may pertain to social cost-benefit analysis (e.g. for infrastructure network programmes or regional environmental taxation schemes), to multiple objective programming models (especially in case of a continuous modelling representation with conflicting policy objectives), or to multi-criteria analysis (in case of the evaluation of a discrete number of environmental-economic policy choices). In a situation of qualitative or fuzzy information, specific qualitative multicriteria decision support techniques are available (see Janssen 1992 and this book, and Munda 1995, and this book). These decision support methods have extensively been used in spatial-environmental policy studies, for instance, land reclamation projects, location policies on nuclear power plants, evaluation of new industrial sites etc. (see for a survey Nijkamp et al. 1992).

We may conclude that in the field of environmental policy support a wide variety of different operational methods does exist, which have proven their feasibility in the past decades.

5. Prospect

The methodology for the integration of socio-economic variables (depicting the pattern and evolution of a local or regional economy) and of ecological variables (mirroring the development of ecosystems in the study area concerned) is usually fraught with many difficulties. In order to map out such complex interactions in a consistent way, it is often appropriate to design a cohesive economic-ecological structure model on the basis of the so-called **satellite** principle (cf. Brouwer 1988). This principle means that the core of interactions between the economy and the environment in a regional system is described in a compact but comprehensive system's model. All other (non-core) phenomena are not represented in full depth and not with all their complex dynamic interactions, but are only depicted in terms of their main linkages to the core. All satellite modules may also have a distinct spatial scale (e.g., for ecosystems, for recreational behaviour, for system-wide efficiency etc.). This core-satellite design ensures a consistent, concise and structured presentation of a compound multidimensional system for a spatial economy, based on a hierarchical modular structure.

Several variables (like landscape or ecological data) can be spatially differentiated, whereas others (like socio-economic data) are often only used in an aggregate manner. This means that the spatial component has to be dealt with carefully in the empirical analysis, which is also the reason why GIS (Geographical Information Systems) is an indispensable element in modern environmental planning studies.

In general, systems theory offers a fruitful background and frame of reference for assessing various effects in a compound spatial-economic and environmental system. In order to develop a practical research methodology for sustainability planning at the local or regional level, various scientific methods may be helpful. Examples are: dynamic systems analysis; spatial impact analysis; spatial-environmental scenario analysis; Geographic Information Systems (GIS) modelling; multi-criteria decision support analysis; spatial simulation studies, and so forth.

It is evident that effective and accessible information systems are vital to spatial-economic and environmental decision-making. The rapid development of digital and electronic technologies, for instance, in the form of digital recording and transmission of sound and pictures, optical fibres for the high speed of transmission of information, super-fast computers, satellite broadcasting and video transmission, offers a new potential for sophisticated voice, data and image transmission. All such information systems may be highly important for the planning of our scarce space, not only on a global scale (e.g., monitoring of rain-forest development), but also on a local scale (e.g., physical planning). Within this framework, spatial information systems are increasingly combined with geographic pattern recognition, spatial systems theory, topology and spatial simulation analysis.

Finally, it is important to stress that the degree of sophistication in spatial-environmental systems modelling should keep pace with the need of decision-makers and stakeholders. Thus, there is a clear need for an increase in user-friendliness of regional-environmental models. Clearly, making a complex system more user-friendly may narrow its range of applications and may make the system more rigid. Proper user support tools are amongst others: accessible source programme documentations; user-oriented scenario visualisation; inclusion of sample runs with graphical results, etc. There is no doubt that, seen from a regional economic and land use perspective, a formidable research challenge lies still ahead of us.

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